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## REMARKS

Please cancel claims 1-33 and 36-73 without prejudice. Applicants submits that claim 35 is amended hereby.

Applicant also submits that the changes to the specification in addition to the "CONTINUATION DATA" are necessitated either by typographical errors or by the correction of the formal drawings. Applicant submits that no new matter is added and changes are solely typographic in essence, and there is no change of claim, scope, and that no new search is necessary.

Please delete the abstract currently on file and replace it with the attached "ABSTRACT OF DISCLOSURE".

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If the Examiner has any questions or comments that would speed prosecution of this

case, the Examiner is invited to call the undersigned at 260/485-6001.

Respectfully submitted,

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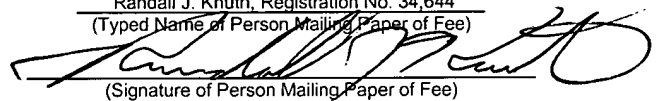
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## MARKED-UP SPECIFICATION

### PLASMA DEVICE

### CONTINUATION DATA

This is <u>a divisional of U.S. Patent Application No. 10/100,533, filed on March 18, 2002, which</u> <u>is</u> a divisional of Patent Application No. 09/355,229 filed on July 26, 1999, the disclosure of <u>each of</u> which is herein explicitly incorporated by reference.

5      Technical Field

The present invention relates to a plasma device.

Background of the invention

Recently, accompanying the increase in chip size of ULSI (ultra large scale integrated circuits), there has been a tendency to increase the diameter of a silicon substrate used as a substrate for the

10     ULSI. Since sheet leaf processing for handling substrates one at a time has become mainstream, if the substrate is increased in diameter there is a need for high speed processing of at least 1mm per minute in order to maintain high productivity if etching and film forming are carried out. In a plasma device for handling an increased diameter substrate enabling high speed processing, it is essential to be able to generate high density plasma having an electron density in excess of $10^{11}$ cm$^{-3}$ and to obtain the flow of

15     a large quantity of gas in order to efficiently remove a large amount of reaction products discharged from the substrate surface as a result of the high speed processing. In order to enable the generation of high density plasma, a parallel plate type plasma device introducing a magnetic field has been developed. As a conventional plasma device of this type, a magnetron plasma etching device using a dipole ring magnet is disclosed in, for example, Japanese Patent Laid Open No. Hei. 6-370.54.

20     Fig. 43 is a schematic diagram of the conventional magnetron etching device using a dipole ring magnet. Fig. 43(a) shows the state at the time of etching, and Fig. 43(b) shows the state at the time of conveying the substrate. In the drawings, reference number 4301 is a vacuum vessel, reference number 4302 is an electrode I, reference number 4303 is a substrate <u>in a space 4315</u>, reference number 4304 is a gas introduction opening, reference numeral 4305 is a show plate, reference numeral 4306 is a dipole

25     ring magnet, reference numeral 4307 is a bellows, reference numeral 4308 is a substrate conveying port, reference numeral 4309 is a gate valve, reference numeral 4310 is a substrate conveying port, reference numeral 4311 is a gas outlet, reference 4312 is a vacuum pump, reference numeral 4313 is a matching circuit and reference numeral 4313 is a high frequency power source.

At the time of etching, source material gas that has been introduced from the gas introduction

30     opening 4304 is discharged from a plurality of small holes in the

within a narrow space inside a container that enables uniform formation of a high quality thin film on a large substrate at a low temperature and at high speed, by causing excitation of uniform high density plasma having a low plasma potential over a large surface area, making supply of source material gas uniform and swiftly removing reaction by-product gases by adopting a structure equivalent to a shower plate. The invention is applicable to plasma processing other than an etching plasma process.

Summary [Disclosure] of the Invention

A plasma device of the present invention ~~comprises~~ comprises:

a container, the inside of which can be internally decompressed, and part of the inside being formed of a first dielectric plate made of material capable of passing microwaves with almost no loss,

a gas supply system for supplying essential source material gas so as to cause excitation of plasma inside the container,

an exhaust system for expelling source material gas supplied into the container and decompressing the inside of the container,

an antenna, located facing an outer surface of the first dielectric plate and comprised of a slot plate and a waveguide dielectric for radiating microwaves, and

an electrode for holding a object to be treated located inside the container, a surface of the object to be treated that is to be plasma processed and a microwave radiating surface of the antenna being arranged in parallel substantially opposite to each other, and the plasma device carrying out plasma processing for the object to be treated, wherein,

a wall section of the container outside the first dielectric plate is of a material comprising matter having a specific conductivity of $3.7 \times 10^7 \, \Omega^{-1}/m^{-1}$ or more, or the inside of the wall section is covered with this material, and

when thickness of the material is d, the specific conductivity of the material is $\sigma$, the magnetic permeability of the vacuum is $\mu_0$, and the angular frequency of microwaves radiated from the antenna is $\omega$, the thickness d is larger than $(2/\mu_0\sigma\omega)^{1/2}$.

A plasma processing method of the present invention is a method using a plasma device comprising a container, the side of which can be internally decompressed, and part of the inside being formed of a first dielectric plate made of material capable of passing microwaves with almost no loss, a gas supply system for

supplying essential source material gas so as to cause excitation of plasma inside the container, an exhaust system for expelling source material gas that has been supplied inside the container and decompressing the inside of the container, an antenna, located facing an outer surface of the first dielectric plate and comprised of a slot plate and a waveguide dielectric, for radiating microwaves, an electrode for holding an object to be treated lcoated inside the container, a surface of the object to be treated that is to be subject to plasma processing and a microwave radiating surface of the antenna being arranged in parallel substantially opposite to each other, and the plasma device carrying out plasma processing for the object to be treated, the power density of microwaves to be input being 1.2 W/cm$^2$ or more. This method assures stable generation of plasma.

A plasma device of the present invention is provided with an electrode I inside a vacuum container, and a substrate to be subjected to processing using plasma is mounted so as to be connected to this electrode I. Magnetic field applying means I and II are provided outside the vacuum container, for the purpose of applying a magnetic field to the inside of the plasma, and at least some of a gas that has been introduced into the vacuum container is expelled through a space between the magnetic field applying means I and II.

A plasma device of the present invention is provided with two parallel plate type electrodes I and II inside a vacuum container, and a substrate to be subjected to processing using plasma is mounted so as to be connected to either the electrode I or the electrode II. Means for applying a magnetic field to the inside of the plasma are provided, and the electrode II comprises a central section, and an outer section connected to a high frequency power source that can be controlled independently of a high frequency power source connected to the electrode I.

A plasma device of the present invention is provided with an exhaust space formed directly communicating with an inlet of vacuum pump, to the side of a film forming space above the substrate.

A plasma device of the present invention ~~comprises~~ comprises:

a container, the inside of which can be internally decompressed, and part of the inside being formed of a first dielectric plate made of material capable of passing microwaves with almost no loss,

a gas supply system for supply essential source material gas so as to cause excitation of plasma inside the container,

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# MARKED-UP SPECIFICATION

an exhaust system for expelling source material gas that has been supplied inside the container and decompressing the inside of the container,

an antenna, located facing an outer surface of the first dielectric plate and comprised of a slot plate and a waveguide dielectric, for radiating microwaves, and

5

an electrode for holding an object to be treated located inside the container, a surface of the object to be treated that is to be subject to plasma processing and a microwave radiating surface of the antenna being arranged in parallel substantially opposite to each other, and the plasma device carrying out plasma processing for the object to be treated, wherein,

an exhaust space formed directly communicating with an inlet of a vacuum pump is provided

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to the side of a film forming space above the substrate.

Brief description of the drawings.

Fig. 1 is a cross section of a device relating to embodiment 1.

~~Fig. 2 is a plan view~~ Figs. 2A and 2B are plan views showing one example of a radial line slot

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antenna used in the device of Fig. 1.

Fig. 3 is the results of a plasma ignition test relating to the first embodiment, showing interdependence between microwave power and chamber material.

Fig. 4 is the results of a plasma ignition test relating to the first embodiment, showing interdependence between plating film thickness and microwave frequency.

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Fig. 5 is a cross section of a device relating to embodiment 1 showing the case where a plating layer is provided on an inner surface of the chamber.

Fig. 6 is a cross section of a device relating to embodiment 1 showing the case where the inner surface of the chamber is covered with a plate member comprising a prescribed material.

Fig. 7 is a cross section of a device relating to embodiment 2.

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Fig. 8 is an enlarged view of region A in Fig. 7, and shows a case where a first dielectric plate comes into contact with a first O ring and a metallic thin film 114 is provided on a vacuum sealing region.

Fig. 9 is an enlarged view of region A in Fig. 7, and shows a case where the first O ring is enveloped by a metallic thin film 5.

Fig. 10 is a cross section of a device relating to embodiment 3.

30

Fig. 11 is a graph showing the ion saturation current density in embodiment 3.

Fig. 12 is a cross section of a device relating to embodiment 4.

Fig. 13 is an enlarged view of region B in Fig. 12.

Fig. 14 is a graph showing the ion saturation current density in embodiment 5.

Fig. 15 is a cross section of a device relating to embodiment 7.

5     Fig. 16 is a schematic diagram of a **tool** for confirming the presence or absence of plasma excitation in embodiment 7.

Fig. 17 is a graph showing a relationship between probe voltage and probe current for embodiment 7.

Fig. 18 is a graph showing a relationship between minimum discharge power and Ar pressure for embodiment 7.

10    Fig. 19 is a partial cross section of a device a device relating to embodiment 8, and shows a case where a **cover plate** is used.

~~Fig. 20 is a partial cross section~~ Figs. 20A and 20B are partial cross sections of the device relating to embodiment 8, and shows a case where a slot is reduced in size.

Fig. 21 is a graph showing the ion saturation current density in embodiment 8.

15    Fig. 22 is a partial cross section of a device relating to embodiment 9.

Fig. 23 is a partial cross section of a device relating to embodiment 10.

Fig. 24 is a cross section of a device relating to embodiment 11.

Fig. 25 is a cross section of a device relating to embodiment 12.

Fig. 26 is a graph showing a relationship between deposition rate of polymer film and chamber internal

20    wall temperature.

Fig. 27 is a cross section of a device relating to embodiment 13.

Fig. 28 is a schematic diagram showing a system when a staged cooler method is adopted in collection and reuse of fluorocarbon type gas in embodiment 14.

Fig. 29 is a graph showing a relationship between average binding energy of fluorine gas and the

25    plasma parameter of the fluorine gas for embodiment 15.

~~Fig. 30 is a graph~~ Figs. 30A and 30B are graphs showing evaluation results of damage caused by plasma irradiation of $AlF_3/MgF_2$ alloy, Fig. 30(a) showing before $NF_3$ plasma irradiation and Fig. 30(b) showing after 2 hours of $NF_3$ plasma irradiation.

Fig. 31 is a graph showing distribution of ion saturation current density for embodiment 16.

30    Fig. 32 is a graph showing distribution of electron temperature for embodiment 16.

Fig. 33 is a graph showing distribution of electron temperature for embodiment 16.

# MARKED-UP SPECIFICATION

Fig. 34 is a schematic diagram of a system for measuring ion current distribution for embodiment 16.

~~Fig. 35 is a schematic~~ Figs. 35A and 35B are schematics showing the structure of a single probe used in measurement of electron temperature and electron density for embodiment 16.

Fig. 36 is a graph showing results of plasma etching in embodiment 17.

Fig. 37 is a schematic diagram showing a combination of a cross section of elements of embodiment 18 and a element withstand voltage measurement system.

~~Fig. 38 is a graph~~ Figs. 38A and 38B are graphs showing results of withstand voltage for embodiment 18.

Fig. 39 is a graph showing results of analyzing chemical binding state of a Si surface, using an X-ray photoelectron spectroscope, for a silicon nitride film in embodiment 28.

Fig. 40 is a schematic diagram showing a combination of a cross section of an element and an element dielectric breakdown injection charge amount measurement system, for embodiment 28.

Fig. 41 is a graph showing results of dielectric breakdown injection charge amount for embodiment 28.

Fig. 42 is a graph showing results of an X-ray diffractometer for embodiment 29.

~~Fig. 43 (a-b) is a schematic diagram~~ Figs. 43A and 43B are schematic diagrams of a conventional magnetron plasma etching device.

Fig. 44 is a schematic diagram showing an example of a plasma device of the present invention.

Fig. 45 is a plan view showing an example of a plasma device of the present invention.

Fig. 46 is a plan view showing an example of a plasma device of the present invention.

Fig. 47 is a plan view showing an example of a plasma device of the present invention.

Fig. 48 is a plan view showing an example of a plasma device of the present invention.

Fig. 49 is a plan view showing an example of a plasma device of the present invention.

Fig. 50 is a plan view showing an example of a plasma treatment device of the present invention.

Fig. 51 is a plan view showing an example of a plasma treatment device of the present invention.

Fig. 52 is a plan view showing an example of a plasma treatment device of the present invention.

Fig. 53 is a plan view showing an example of a plasma device of the present invention.

Fig. 54 is a plan view showing an example of a plasma device of the present invention.

Fig. 55 is a drawing showing an example of means for applying a high frequency to electrode II.

Fig. 56 is a drawing showing an example of means for applying a high frequency to electrode II.

Fig. 57 is a graph comparing displacement in the related art and this embodiment.

5      Fig. 58 is a drawing showing the manufacturing flow when producing a pattern with this embodiment.

Fig. 59 is a graph comparing specific resistance in the related art and this embodiment.

Fig. 60 is a schematic diagram showing a combination of a cross section of elements of this embodiment and a withstand voltage measuring system.

10      ~~Fig. 61 is a graph~~ Figs. 61A and 61B are graphs showing results of measuring withstand voltage for this embodiment and the related art.

Fig. 62 is a plan view of a plasma device of the related art.

Fig. 63 is a graph showing distribution of film thickness inside the surface of a wafer of silicon oxide film.

15      Fig. 64 is a schematic diagram showing a combination of a cross section of elements of this embodiment and a system for measuring dielectric breakdown injection charge amount.

Fig. 65 is a graph showing results of measuring dielectric breakdown injection charge amount.

Fig. 66 is a graph showing distribution of film thickness inside the surface of a wafer of direct nitride film.

20      Fig. 67 is a graph showing results of a system for measuring barrier properties of a direct nitride film.

Fig. 68 is a graph showing a relationship between amounts of oxygen and carbon, and total flow amount of process gas.

Fig. 69 is a drawing showing an example of a mask structure for X ray lithography.

25      Fig. 70 is a schematic diagram showing a diamond thin film permeability measurement system.

Fig. 71 is a graph showing the results of evaluating a diamond thin film.

Fig. 72 is a graph showing dependence of surface roughness of a polycrystalline silicon thin film on total flow amount.

Fig. 73 is a graph showing dependence of uniformity of a glass substrate surface of a polycrystalline silicon thin film on total gas flow amount.

Fig. 74 is a graph showing dependence of crystallite size of polycrystalline silicon on total gas flow amount.

Fig. 75 is a graph showing dependence of the amount of hydrogen in a polycrystalline silicon film on total gas flow amount.

Fig. 76 is a graph showing dependence of the specific resistance of polycrystalline silicon (P dopant) on total gas flow amount.

Fig. 77 is graph showing dependence of the in-plane uniformity of a SiNx film on total gas flow amount.

Fig. 78 is a graph showing dependence of the withstand voltage of a SiNx film on total gas flow amount.

Fig. 79 is a graph showing dependence of the atomic level compositional ratio of Si to N in a SiNx film on total gas flow amount.

Fig. 80 is a graph showing dependence of the deposition rate of a fluorocarbon film on total gas flow amount.

Fig. 81 is a graph showing dependence of the deposition rate of a fluorocarbon film on total gas flow amount.

Fig. 82 is a graph showing the dependence of additional gas flow on the deposition rate of a BST film.

Fig. 83 is a graph showing the dependence of the in-place uniformity of wafer of a deposition rate of a BST film on additional gas flow.

Fig. 84 is a cross section of a device manufactured using the present invention.

~~Fig. 85 is a drawing~~ Figs. 85A and 85B are drawings showing process cluster tools for formation of an insulating film and formation of tantalum silicide.

~~Fig. 86 is a drawing~~ Figs. 86A and 86B are drawings showing distribution of a subthreshold coefficient of a tantalum oxide gate insulation film MOSFET.

~~Fig. 87 is a graph~~ Figs. 87A and 87B are graphs showing initial damage rates of samples of the present example and the related art.

~~Fig. 88 is a drawing~~ Figs. 88A and 88B are drawings showing in-place uniformity of a tantalum oxide capacitor.

Fig. 89 is a graph showing displacement of a turbo molecular pump.

5414a magnetic field applying means

5415 vacuum pump

5501 electrode IIa

5502 electrode IIb

5    5503 target

5504 high frequency power supply I

5505 matching circuit I

5506 high frequency power supply II

5507 matching circuit

10    5508 phase control circuit

5601 electrode IIa

5602 electrode IIb

5603 target

5604 high frequency power supply

15    5605 matching circuit


## DETAILED DESCRIPTION OF THE INVENTION

Best mode of practicing the invention

(1) In the plasma device of the present invention, an antenna for irradiating microwaves is provided

20    on the outer side of a container, with a first dielectric plate interposed between the antenna and the container.

Because the first dielectric plate is made of a material that can transmit microwaves with almost no loss, it

becomes possible to excite the plasma inside the container by irradiating microwaves from outside the

container, so that the antenna is not directly exposed to the source material gas and the reaction by-product

gas. Also, an electrode for holding an object to be treated is provided inside the container, and a microwave

25    emitting surface of the antenna and a surface of the object to be treated that is to be subjected to plasma

processing are arranged opposite to each other and substantially in parallel, which means that it is easy to

reduce a space between these two surfaces, and it is possible to increase the flow rate of source material gas

and reaction by-product gas, and to swiftly remove the reaction by-product gas. Further, a wall section of

the container other than the first dielectric plate is either a member comprising a material having specific

30    conductivity higher than that of aluminum, or the outside of this wall section is covered with the member,

and if thickness of the material is d, the specific conductivity of the material is $\sigma$, the magnetic permeability

of the vacuum is $\mu_0$, and the angular frequency of microwaves radiated

15

In the plasma device of Fig. 44, a dipole ring magnet having a plurality of permanent magnets aligned in an annular shape are used as magnetic field applying means 4413, as shown in the drawing. The permanent magnets constituting the dipole ring magnet are aligned so that a direction of magnetization passes through one rotation as the magnet positions go halfway round.

5 Gas introduced from the gas inlet 4412 is discharged into a process space from a plurality of small holes of the shower plate 4410. This introduced gas, and reaction product gas discharged from a substrate surface, is expelled from a plurality of vacuum pumps 4414 to the outside via a space interposed between the magnetic field applying means 4413a and 4413b to the side of the substrate. A comparatively wide space is provided in an upper part of the vacuum pump 4414 so 10 as to cause the gas conductance to be lowered. A projection surface of the upper section of the vacuum container 4406 is shown in Fig. 44(a). The vacuum container 4401 has a shape close to a square, and four vacuum pumps 4402 are provided in the corners of this vacuum container 4401. In this way, if exhaust is carried out by a plurality of vacuum pumps aligned around the substrate substantially axisymmetrical to an axis perpendicular to the substrate surface and running through 15 the center of the substrate, uniform gas flow can be realized in a rotational direction above the substrate, without causing hardly any lowering of gas conductance. That is, it becomes possible to cause a large amount of gas to flow up to a value close to the tolerance of the vacuum pump, and it is possible to handle an ultra high speed process for a large diameter substrate.

Here, the electrode II 4411 is a ring shaped metallic plate, and is provided so as to allow 20 improvement of in-plane uniformity of plasma close to the surface of the substrate 4408. High frequency power output from the high frequency power supply II 4418 is applied to the electrode II 4411 through the matching circuit II 4417. If a balance of electron drift on the surface of the electrode II 4411 and the electron drift on the surface of the substrate 4408, caused by a magnetic field applied by application of appropriate high frequency power to the electrode II 4411, is 25 obtained, plasma close to the surface of the substrate 4408 is made almost totally uniform. If uniformity of the plasma surface close to the surface of the substrate 4408 is good with application of high frequency to the electrode II 4411, or if no problem arises even with non-uniformity, it is not particular necessary to provide the electrode II 4411.

In the plasma device of Fig. 43, the shower plate [[405]] 4305 is grounded, but it does not

necessarily need to be grounded and it does not matter if a high frequency is applied. Also, it does not matter [[of]] if a shower plate is not used and gas is discharged from another section.

Fig. 45 is a plan view showing an example of a plasma device of the present invention. Reference numeral 4501 is a vacuum container, reference numeral 4502 is a gas inlet, reference numeral 4503 is a̲ magnetic field applying means, reference numeral 4504 is a gas outlet, and reference numeral 4̶5̶0̶0̶0̶5̶ 4505 is a gate valve. A surface of the vacuum c̶o̶n̶t̶a̶i̶n̶e̶r̶4̶5̶0̶1̶ container 4501 projecting from an upper part is approximately triangular in shape, and three vacuum pumps are placed in the corner sections. Other aspects of the plasma device are the same as that described for Fig. 44. With the plasma device of Fig. 45, a distance between a gate valve 4505 and the substrate is smaller than in the plasma device shown in Fig. 44. This is suitable for the case when the stroke of a substrate conveyance arm is restricted.

Fig. 46 is a plan view showing an example of a plasma device of the present invention. Reference numeral 4601 is a vacuum container, reference numeral 4602 is a gas inlet, reference numeral 4603 is magnetic field applying means, reference numeral 4604 is a gas outlet, and reference numeral 4605 is a gate valve. Two vacuum pumps are placed in the vacuum container 4602. Apart from this, the plasma device is the same as that described in Fig. 44. With the plasma device of Fig. 46, similarly to the device of Fig. 45, a distance between a gate valve 4505 and the substrate is smaller than in the plasma device shown in Fig. 44. This is suitable for the case when the stroke of a substrate conveyance arm is restricted and when there is a margin in the expel capacity of the vacuum pump.

Fig. 47 is a plan view showing an example of a plasma device of the present invention. Reference numeral 4701 is a vacuum container, reference numeral 4702 is a gas inlet, reference numeral 4703 is magnetic field applying means, reference numeral 4704 is a gas outlet, reference numeral 4705 is a vacuum pump, and reference numeral 4706 is a gate valve. Two vacuum pumps are placed sideways in the vacuum container 4702. Apart from this, the plasma device is the same as that described in Fig. 44. The footprint of the plasma device including the vacuum container 4701 and the vacuum pump 4705 is larger, but the size of the vacuum container 4701 becomes a minimum. This is suitable for the case when the stroke of a substrate conveyance arm is restricted and when there are restrictions on the size of the vacuum container.

possible to use either of the following two methods as means of applying to the electrode II.

(a) Fig. 55 shows a first method. A high frequency power supply I 5504, matching circuit I 5505, high frequency power supply II 5506 and matching circuit II 5507 are connected to divide electrodes IIa 5501, electrode IIb 5502, for respectively applying a high frequency to the target 5503, electrode IIa and electrode IIb , and the phases of the two high frequencies are made opposite and introduced by connecting a phase adjustment circuit 5508 to the electrode IIb side.

(b) Fig. 56 shows a second method. Reference numeral [[5501]] 5601 represents a divided electrode IIa. Reference numeral [[5502]] 5602 represents electrode IIb and reference numeral [[5503]] 5603 represents a target. High frequency oscillations from the high frequency power supply [[5504]] 5604 propagate to the matching circuit [[5505]] 5605 and are grounded through a balanced/non-equilibrium circuit (balance). Using this circuit circuit, high frequency having mutually revered phase is introduced.

(3) Taking Fig. 53 as an example, the plasma device of the present invention is provided with the exhaust space 5315 formed directly contacting the intake port 5314 of the vacuum port 5303, to the side of the film forming space 5313 above a substrate 5308.

By providing the exhaust space 5315, being a comparatively wide space, to the side of the film forming space 5313, source material gas that has been introduced from outside, or reaction product gas, is expelled without lowering the gas conductance, and it is possible to make a large amount of gas flow, close to the capacity of the vacuum pump.

This exhaust space 5315 is preferably provided at a number of places, and in this case the spaces are preferably arranged at positions symmetrical around the substantial center of the substrate 5308. If a plurality of such spaces are symmetrically provided, the above described effects are even more remarkable.

The heigh b of the exhaust space 5315 is preferably as large as is practicable.

The width L of the exhaust space 5315 is preferably at least two times the height a of the film formation space 5313. The uniformity of the gas flow is dramatically improved by the fact that the width L is two times the height a.

Embodiments

26

approximately 10mm to 60mm.

~~Fig. 2 is a schematic plan view~~ Figs.2A and 2B are schematic plan views of the radial line slot antenna 201 shown in Fig. 1 look from above. Hole sections (hereafter referred to as slots) 110 penetrating through antenna slot plate 106 are arranged in the slot plate, but the arrangement of the

5      slots 110 is not limited to that shown in ~~Fig. 2.~~ Figs. 2A and 2B.

The slots 110 are configured having two slots 111a and 111b constituting a single pair, and the two slots in a pair are arranged at right angles to each other at a distance of a quarter of a wavelength $\lambda$g of an incident wave passing through the coaxial tube 107 to the antenna 201. The pairs comprised of a slot 11a and a slot 11b, namely the slots 110, are each capable of outputting

10     circularly polarized electromagnetic waves, and a plurality of slots 110 are numerously concentrically provided. Besides the concentric arrangement the slots 110 can also be arranged spirally. Although this embodiment is not limited to this concentric arrangement, the slots 110 are provided in this way so as to uniformly radiate electromagnetic waves within a large surface area.

The present invention is not limited to radiation of concentrically polarized electromagnetic

15     waves, and it is possible to use linear polarization, but concentric polarization is preferred.

Reference number 107 is a coaxial tube for supplying microwaves to the antenna slot plate 106, and is connected to a microwave power supply through a coaxial tube - waveguide converter, not shown, a waveguide and a matching circuit.

There is also a need for means for conveying the object to be treated 104 into and out of the

20     chamber 101, but this is omitted from Fig. 1.

In this example, microwaves (frequency = 8.3GHz) are introduced to the radial line slot antenna 201 using the coaxial tube 107, electromagnetic waves are radiated from the antenna 201 and plasma 105 is excited inside the space 5 of the chamber 100. However, there was no excitation of plasma 105 within the space 5 (207) with the SUS chamber 101.

25     Accordingly, plating layers (7) comprising lead, tantalum, tungsten, aluminum, gold, copper and silver are coated on an inner surface of the SUS chamber 101 and the above described plasma ignition test was carried out. At this time, as the process gas Ar gas was used, and gas pressure was 500mTorr.

Fig. 3 shows the results of the plasma ignition test. At this time, the thickness of the

28

6 (304) at low power.

Contrary to this, by making the microwave frequency high (for example 5.0 GHz), and narrowing the width tg of the space 6 (304) to 0.7mm or less, even if microwave power is delivered up to 1600W (power density $1.27\text{W/cm}^2$) plasma is not excited inside the space 6 (304).

5        Accordingly, in the plasma device shown in Fig. 15, in order to stop plasma excitation in the space 1 (208) between the first dielectric plate 102 and the second dielectric plate 116, microwave frequency input to the antenna is made at least 5.0GHz, and the width of the space 1(208) is made 0.7mm or less.

Also, in the plasma device shown in Fig. 15, when a pressure 1 (P1) of the space 1 (208)

10        between the first dielectric plate 102 and the second dielectric plate 116, and a pressure 2 (P2) of space 2 (209) surrounded by the second dielectric plate 116 and wall sections (chamber) 101 of the container other than the second dielectric plate 116, and where an electrode 109 for holding the object to be treated 104 is arranged, have the relationship P1 > P2, it was confirmed that plasma excitation did not occur in the space 1 (208). Particularly, it is understood that when P1 is

15        sufficiently high compared to P2, for example when there was a pressure difference of about 10 times, these effects were more remarkable.

Accordingly, by providing means 5 for generating a pressure difference so that the pressure 1 (P1) of the space 1 becomes higher than the pressure 2 (P2) of the space 2 (209) it is possible to prevent plasma excitation in the space 1 (208).

20        (Embodiment 8)

With this embodiment, in the plasma device shown in Fig. 15, the effects were studied of either reducing in size, shielding, or not providing at all, those slots, among slots (hole portions penetrating the slot plate) provided in the slot plate constituting the antenna, arranged at sections where the density of plasma generated in the space 2 (209) is locally high.

25        Fig. 19 is a schematic cross sectional drawing showing the slot plate when a shielding plate 119 is provided on the slots 110' positioned close to the center of the slot plate. ~~Fig. 20 is a schematic plan view~~ Figs. 20A and 20B are schematic plan views showing the slot plate when the size of the slots 110' positioned close to the center of the slot plate is reduced. Fig. 20(b) is an enlarged view of a region A of Fig. 20(a).

## MARKED-UP SPECIFICATION

In ~~Fig. 20~~ Figs. 20A and 20B, the case is shown where the length is shortened for only two rings of slots from the center of the slot plate, but reduction in size of the lots can be realized by, for example, shortening the slot length.

Fig. 21 shows results of studying the density of plasma generated at the space 2 (209), using the slot plate shown in Fig. 19. In Fig. 21, slot A, slot B and slot C are the names respectively given to the slot distributions for the case when the shielding region is small, the case where the shielding region is intermediate in size, and the case where the shielding region is large. From Fig. 21 it will be understood that with slot A, the density of plasma at the center of a measuring electrode is raised. By arranging the shielding plate 119 at this portion so that slot distribution is slot B, it can be expected to make the plasma density uniform. However, if the shielding region is made wider, as in slot C, conversely to slot A the plasma density rises at the outer edge of the electrode.

Accordingly, by providing a shielding plate 119 having an appropriate shielding region, the output of electromagnetic waves radiated from the slots is reduced, and the density of excited plasma can be made even more uniform.

A shielding plate 119 that can hope to achieve the above describe operation and effect preferably has a shape and size so as to shield the slots of the slot plate. Namely, it goes without saying that either by reducing the slot size or even using a method of not providing any slots, the same effects can be anticipated as int eh case where the slots are shielded.

(Embodiment 9)

With this embodiment, in the plasma device shown in Fig. 15, the effects were studied of providing means 6 for maintaining the antenna at a fixed temperature close to the antenna, and means 7 for maintaining the temperature of the first dielectric plate at a fixed temperature close to the first dielectric plate.

In the plasma device shown in Fig. 15, as shown in Fig. 22, structures 120 and 121 capable of maintaining the antenna guide 108, waveguide dielectric plate 102, antenna slot plate 106, and first dielectric plate 102 at a fixed temperature are provided close to the antenna guide 108. The structures 120 and 121 are equivalent to the means 6 and the means 7.

In this case, the antenna slot plate 106 is arranged so as to be completely stuck to the waveguide dielectric plate 103. By having this arrangement, if a gap exists between the antenna slot plate 106 and the waveguide dielectric plate 103, surface waves will be generated at that part, and it is possible to effectively avoid a phenomenon where it is

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becomes high as binding energy falls. Plasma energy does not depend largely on binding energy of gas molecules. From this it will be understood that $NF_3$ is an extremely suitable gas for self cleaning. Accordingly, when a self cleaning structure is required the inner walls of the container must have excellent plasma resistance and it is best to use an alloy such as $AlF_3/MgF_2$.

5 ~~Fig. 30 shows~~ Figs. 30A and 30B show the results of evaluating damage caused by plasma irradiation of $AlF_3/MgF_2$ alloy when is used as the chamber inner wall material of the device of Fig. 15, and gas having a small gas molecule binding energy (such as NF3) is used as cleaning gas. Fig. 30(a) is a profile of the $AlF_3/MgF_2$ alloy in a depth direction using XPS (X ray photoelectron spectroscopy) before $NF_3$ plasma irradiation, and Fig. 30(b) is a profile after two hours of $NF_3$

10 plasma irradiation. From the results shown in ~~Fig. 30~~ Figs. 30A and 30B, it will be understood that there is hardly any damage attributable to plasma irradiation.

Accordingly, when there is a need to have a self cleaning structure in the device the container inner walls must have excellent plasma resistance and it is best to use $AlF_3/MgF_2$ alloy. (Embodiment 16)

15 With this embodiment, in the plasma device of Fig. 15 and antenna 201 is located outside the container 101 via the first dielectric plate 102, and plasma excitation is caused by introducing microwaves through a coaxial tube 107 and radiating electromagnetic waves inside the container 101.

Fig. 31 is a graph showing the results of measuring distribution of ion saturation current,

20 Fig. 32 is a graph showing the results of measuring distribution of electron temperature, and Fig. 33 is a graph showing the results of measuring distribution of electron density.

From Fig. 31 to Fig. 33 it will be understood that with the plasma device of the present invention, uniform plasma excitation can be caused by covering high density plasma having a ion saturation current of at least $14mA/cm^2$, electron density in the region of 1.eV (15000K) and

25 electron density of at least $10^{12}$ over a large surface area of diameter 300mm or more inside the container 101.

Fig. 34 is a schematic drawing of a system for measuring the ion current distribution. This is measurement of ion current distribution using a disk-shaped electrode 401. The disk-shaped electrode 401 was used in place of the object to be treated 104 and electrode 109 in the plasma

30 device shown in Fig. 15.

## MARKED-UP SPECIFICATION

In Fig. 34, reference numeral 401 is the disk-shaped plate, reference numeral 402 is a pin, reference numeral 403 is an ~~aluminium~~ aluminum wire, reference number 404 is a resistor, reference numeral 405 is an operation amplifier, reference numeral 406 is an A-D converter, reference numeral 407 is a computer, reference numeral 408 is a stepping motor and reference numeral <u>409</u> is a power supply.

The disk-shaped electrode 401 in Fig. 34 is a piece of disk-shaped ~~aluminium~~ aluminum having a diameter of 300mm$\phi$ and nine pins 402 are embedded in the top of the disk-shaped electrode 401 an equal distance apart on a line running from the center to a point at a radius of 140mm.

Electric current flowing from the plasma to the pins 402 is taken outside the chamber through ceramics-coated ~~aluminium~~ aluminum wires 403 connected to the pins 402 and current introduction terminals (not shown). A voltages of -20V relate to the potential of the chamber is applied to the pins 402, and only positive ions flow in the plasma. A potential generated by this positive ion flow is converted to a voltage signal by the resistor 404, and after being amplified by the operational amplifier 405 is converted to a digital signal by the 16 channel A-D converter 406 and transmitted to the computer 407.

The ~~aluminium~~ aluminum electrode 401 is covered with polyimide tape (not shown). Measurements of rotation of the electrode 401 by the stepping motor 408, and measurements of ion current by the A-D converter are synchronized using the computer 407. Measurement of ion current is carried out 200 times for each pin 402 per rotation of the electrode 401, to obtain a fine two dimensional distribution.

~~Fig. 35 is a schematic diagram~~ Figs. 35A and 35B are schematic diagrams showing a single probe system used in measurement of electron temperature and electron density in this example.

If the probe is inserted into a section where the microwave power density is large, as shown in ~~Fig. 35~~ Fig. 35A, the probe tip (tungsten wire, 0.1mm$\phi$) 601 is heated by the microwaves, and there is a possibility that thermoelectrons will be discharged. There is also a possibility that ionization will occur frequently inside the probe seal. In either case it becomes impossible to obtain a voltage current characteristic of an ordinary single probe.

Therefore, 0.5mm diameter silver wire 602 wound in a spiral manner is arranged clearing a gap at the edge of the probe tip 601 for the purpose of shielding microwaves. The silver wire has low resistance and is not heated by the. Also, the use of comparatively fine

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(3) A gate electrode 704 of Al (thickness 1000nm) was formed on the field oxidation film 702 and the gate oxidation film 703 by a vapor deposition method.

(4) The probe 705 was brought into contact with the gate electrode 704, a d.c. voltage was applied to the object to be treated 701 formed of the n type Si wafer via the gate electrode 704, and the voltage at

5      which the gate oxidation film 703 suffered dielectric breakdown (namely the withstand voltage) was measured using the voltmeter 706.

~~Fig. 38 is a graph~~ Figs. 38A and 38B are graphs showing the results of measuring withstand voltage. Fig. 38A [[38(a)]] shows the case when the gate oxidation film is manufactured using the device of the present invention. On the other hand, Fig. 38B [[38(b)]] shows the case when the gate oxidation

10     film is manufactured using a device of the related art. With a conventional device, plasma is generated by applying a high frequency of 100MHz to parallel plate type electrodes, and the gate oxidation film is formed.

In ~~Fig. 38~~ Fig. 38A, the horizontal axes represent withstand voltage and the vertical axes represent the frequency with which elements were obtained for each withstand voltage. For example, the bar graph

15     at the 10MV/cm part of the horizontal axis is the frequency of occurrence of elements having withstand voltage in the range 9.5 - 10.4MV/cm. The number of elements measured was 30 for each of Figs. 38A and 38B ~~Fig. 38(a) and Fig. 38(b)~~.

The following points become clear from ~~Fig. 38~~ Figs. 38A and 38B.

① Elements manufactured using the device of the related art have a wide withstand voltage

20     distribution (that is, uniformity is bad) and average withstand voltage is 10.2MV/cm ~~[Fig. 38(b)]~~ [Fig. 38B].

② Elements manufactured using the device of the present invention have a narrow withstand voltage distribution (that is, uniformity is good) and a high average withstand voltage of 11.9MV/cm can be obtained, so it is understood that the film quality of the gate oxidation film has been improved ~~[Fig.~~

25     ~~38(a)]~~ [Fig. 38A].

Accordingly, by carrying out direct oxidation using the plasma device provided with the radial line slot antenna of the present invention, it is possible to form an oxidation film having high uniformity and high withstand voltage, which means that it was confirmed that elements having excellent withstand voltage could be manufactured stably.

30     In this example, the device of the present invention has been applied to a plasma oxidation device for oxidizing the surface of an object to be treated at a low temperature, but

reference numeral 4007 is voltage applying means, and reference numeral 4008 is an ammeter.

The formation and withstand voltage measurement of the element shown in Fig. 60 was carried out through the following sequence of events. After a field oxidation film 4002 (thickness:800nm) comprising SiO2 has been [[has]] as formed on the n-type Si wafer using a thermal oxidation method

5      [($H_2 + O_2$) gas, $H_2$ = 1 l/min, $O_2$ = 1 l/min, temperature of object to be processed = 1000°C] part of the field oxidation film 4002 is subjected to etching processing and the surface of the n-type Si wafer 4001 is exposed.

Only the exposed surface of the n-type Si wafer 4001 was subjected to direct nitridation using the plasma device of the present invention to form the gate oxidation film 4003 (surface area = 1.0 x 10⁻

10     $^4cm^2$) formed of $SiO_2$. The film formation conditions at this time were: film formation gas (Ar + $O_2$); gas pressure 30mTorr; partial pressure ration Ar:$O_2$ = 98%:2%; microwave power 700W; oxidation processing time 20 minutes; the substrate was held in an electrically floating state and the temperature of the object to be processed was 430°C. However, the film formation conditions are not thus limited.

A gate electrode 4004 (thickness 1000nm) formed of Al was formed on the field oxidation film

15     4002 and the gate oxidation film 4003 using a vapor deposition method.

The probe 4005 was brought into contact with the gate electrode 4004, a d.c. voltage was applied to the object to be processed 40001 4001 formed of the n-type Si wafer, through the gate electrode 4004, and the potential at which the gate oxidation film 4003 suffered dielectric breakdown (namely, withstand voltage) was measured using the voltmeter 4006.

20     Fig. 61 is a graph Figs. 61A and 61B are graphs showing the results of measuring withstand voltage. Fig. 61(a) Fig. 61A shows the case of the gate insulation film formed by with the device of the present invention, while Fig. 61(b) Fig. 61B shows the case of a gate insulation film formed by with the device of the related art.

Fig. 62 shows a plan view of the plasma device using a radial line slot antenna having the

25     exhaust system of the related art. The only difference from a device using the exhaust system of the present invention is the exhaust system. The exhaust system of the present invention has a comparatively wide space provided above the vacuum pump, and expulsion in carried out from a plurality of vacuum pumps arranged spaced substantially equal distances apart at the side of the substrate, it is possible to have a gas flow uniformly above the substrate in a rotational direction

30     substantially without lowering the gas conductance.

Specifically, it becomes possible to cause a large amount of gas to flow up to the capacity of the vacuum pump, and it is possible to handle ultra high speed processing of a large diameter substrate. Conversely, because the exhaust system of the related art uses vacuum pump expulsion in only one direction, the space above the vacuum pump is narrow and the gas conductance is lowered, it is not

5    possible to realize uniform gas flow above the substrate. As a result, it is not possible to make a large amount of gas flow and it is impossible to handle high speed processing of a large diameter substrate.

In ~~Fig. 61~~ Figs. 61A and 61B, the horizontal axis represents withstand voltage and the vertical axis represents frequency of occurrence of elements that obtained each withstand voltage. For example, the bar graph of the horizontal axis 10MV/cm is the frequency of occurrence of elements having a

10    withstand voltage in the range 9.5 - 10.4 MV/cm. The number of elements measured was 30 in each of ~~Fig. 61(a) and 61(b)~~ Figs. 61A and 61B. From ~~Fig. 61]~~ Figs. 61A and 61B the following point becomes clear.

Elements formed using the device provided with the exhaust system of the related art have a wide distribution of withstand voltage (namely bad film quality uniformity), and an average withstand

15    voltage of 10.3 MV/cm ~~[Fig. 61(b)]~~ [Fig. 61B].

Elements formed using the device of the present invention have a narrow distribution of withstand voltage (namely good film quality uniformity), and a high average withstand voltage of 11.5 MV/cm can be obtained, which means that the film quality of a gate oxidation film is improved ~~[Fig. 61(a)]~~ [Fig. 61A].

20    Fig. 63 is a graph showing distribution of film thickness of the inner surface of wafer surface of the Si oxidation film. The horizontal axis represents distance from the center of the wafer and the horizontal axis represents film thickness of the direct oxidation film.[[,]] The film thickness of the direct oxidation films formed with the device provided with the exhaust system of the related art has low uniformity. On the contrary, the film thickness of direct oxidation films formed with the device of

25    the present invention are almost constant at the wafer surface, and uniformity is high. Accordingly, since it is possible to form oxidation films having high uniformity and high withstand voltage it was confirmed that it was possible to stably manufacture elements having excellent withstand voltage.

In this embodiment, the device of the present invention has been applied to a plasma oxidation device for oxidizing a Si surface of a substrate at low temperature, but it is not limited to a Si surface

30    and it was confirmed that it was also possible to obtain oxidation films

(Embodiment 44)

Fig. 84 is a cross section of a device manufactured using the present invention.

All the following processes, except for wafer cleansing and lithography processes were carried out using a cluster tool.

5    Part of the cluster tool is shown in ~~Fig. 85~~ Figs. 85A and 85B. The characteristic of this cluster tool is that by connecting between each process chamber using an Ar or $N_2$ tunnel, thin film formation can be carried out continuously under an extremely pure atmosphere without exposing the semiconductor, metal, or insulator on the substrate to the atmosphere at all. Also, each process chamber achieves an ultra high vacuum state of the ultimate vacuum of $10^{-10}$ Torr, but at the time of conveying

10    the wafer, a number of mTorr to several tens of Torr is maintained using very pure Ar or $N_2$ and contamination of the wafer surface by organic matter or moisture etc. is prevented. Further, conveyance between each cluster is carried out using a port sealed encapsulated with $N_2$ or dry air, and wafer cleansing and lithographic processing is also carried out in an $N_2$ or dry air atmosphere, and it is possible to carry out processing that completely excludes all sorts of impurity elements from the

15    atmosphere.

An SOI wafer from which an oxidation film in the vicinity of the surface has been removed is loaded into the cluster tool 6101. After loading, a Ta thin film is formed to a thickness of 1 - 50nm with a plasma processing device using a uniform horizontal magnetic field of the present invention shown in Fig. 54. At this time, by controlling a high frequency applied to the entire surface of the wafer, ion

20    irradiation energy is controlled and it is possible to obtain Ta of desirable film quality. Next, the wafer was introduced into the plasma processing device using the radial line slot antenna of the present invention shown in Fig. 53, plasma oxidation was carried out in a Ar/He/$O_2$, Xe/$O_2$ or Xe/He/$O_2$ atmosphere, only the Ta film formed in the previous process was oxidized and a tantalum oxide thin film 6001 was obtained. The pressure at the time of plasma oxidation was 3 - 500 mTorr and the wafer

25    was temperature controlled to 300 - 500°C. A Ta thin film 6002 constituting a gate electrode was also formed to a thickness of 0-1 - 2μm with the plasma processing device using the uniform horizontal magnetic field of the present invention shown in Fig. 54. Consecutively, a CVD NSG film was formed to a thickness of 1 - 50 nm using the plasma processing device using the radial line slot antenna of the present invention shown in Fig. 53. With this cap processing, it is possible to selectively form tantalum

30    oxide only on the gate side surface, and

it is easy to carry out etching processing at the time of forming contact holes on the gate electrode with a high selectivity.

Next, using the plasma processing device using the uniform horizontal magnetic field of the present invention shown in Fig. 44, gate etching is carried out. The process for forming the barrier metal in this step is shown in detail in Fig. [[85]] 55. By using this device, in-lane uniformity is high even for a large diameter substrate, and fine processing is possible. High purity ion injection is carried out in a self aligned manner, and after activation annealing for 450 - 550°C a source drain region 6003 was formed (a). Oxidation was carried out similarly to previously, as side wall 6004 processing, using the plasma processing device using the radial line slot antenna of the present invention shown in Fig. 53(b).

After $SiO_2$ of the Si surface has been removed by wet etching, a Ta film is formed to 2 - 100nm (c). Ta and S/D section Si of the surface are made amorphous and mixed by I/I, and after that tantalum silicide 6006 is formed by annealing (d). After that, patterning is performed (e) and after Ta has been etched using the plasma processing device using the uniform horizontal magnetic field of the present invention shown in Fig. 44 (f), a cap $SiO_2$ is removed by wet etching (g). After that, barrier metal formation 6006 is carried out (h). Next, the wafer was introduced into the plasma processing device using the radial line slot antenna of the present invention shown in Fig. 53, and plasma nitridation was carried out in an N2, $Ar/N_2$, or $Xe/N_2$ atmosphere. Film thickness was 10 - 500nm. The pressure at the time of plasma oxidation was 3 - 500 mTorr and the wafer was temperature controlled to 300 - 550°C.

Also, a CVD NSG film 6007 is formed using the plasma processing device using the radial line slot antenna of the present invention shown in Fig. 53, flattened by CMP, and contact etching is carried out using the plasma processing device using the uniform horizontal magnetic field of the present invention shown in Fig. 44.

Capacitor formation is carried out by oxidizing a surface layer to 5 - 500nm after film formation of the lower Ta electrode 6008 to a thickness of 0.1 - 2μm, forming tantalum oxide 6009, and film forming the upper Ta electrode 6010 to 0.1 - 2μm. These processes are also carried out with the plasma processing device using the radial slot line antenna and the plasma processing device using the uniform horizontal magnetic field of the present invention.

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# MARKED-UP SPECIFICATION

After formation of these elements, formation of Cu wiring 6011 is carried out and the device is completed. In the case where Ta nitride is used as barrier metal between the wiring, a process for forming barrier metal on the gate electrode is applied accordingly.

A tantalum oxide gate insulation FET or tantalum oxide capacitor formed int his way was electrically evaluated.

~~Fig. 86 shows~~ Figs. 86A and 86B show distribution of a subthreshold coefficient of a tantalum oxide gate insulation MOSFET. A device having only the gate insulation film formation using the plasma device of the related art has a largely distributed subthreshold coefficient, but in the present invention high uniformity is realized.

The initial failure rate of MOSFETs in the case of carrying out a process of forming titanium nitride formation, as barrier metal, using the plasma device of the present invention, and the initial failure rate of examples that used the present invention, as well as samples after carrying out heating tests for 24 hours at 700°C in the atmosphere, as shown in ~~Fig. 87~~ Figs. 87A and 87B. With the technique of the related art, initial failure rate at the wafer edge is low, but Cu used as wiring material in this case diffuses into imperfect tantalum nitride. In the present invention, the entire surface of the wafer exhibits a low failure rate.

~~Fig. 88 shows~~ Figs. 88A and 88B show in-plane uniformity of the capacitance of a tantalum oxide capacitor. In the related art, there is a tendency for film thickness to increase in the radial direction, but with the present invention it is possible to obtain a uniform capacitance over the entire surface.

In this embodiment, an SOI wafer is used as the starting wafer, but it goes without saying that it is also possible to obtain the same results in this embodiment if a Si wafer, Si epitaxial wafer, metal substrate SOI wafer, GaAs wafer or diamond wafer, or a substrate having a thin film of Si, GaAs or diamond formed on the surface of quartz, glass, ceramics or plastic etc. are used.

Ta is used as a MOSFET gate electrode in this embodiment, but it goes without saying that the same effects can be obtained in $n^+$ polysilicon or $p^+$ polysilicon is used. In this embodiment a mixed gas of a carrier gas of Ar, Xe, He, etc. and $O_2$ is used as oxidation process gas, but it goes without saying that the same effects can be obtained with this embodiment of a mixed gas of another carrier gas and an oxide (for example $H_2O$, $NO_x$ etc.) is used as the mixed gas.

drawing it will be understood that in a high pressure region exhaust rate is decreased

accompanying increased pressure. It will also be understood that compared to a pump having a

small exhaust rate, a pump having a large exhaust rate has a further decrease in exhaust rate from

a low pressure region. In a pump having a small exhaust rate of 220 1/sec, substantially no

5       decrease in exhaust rate was observed at a low pressure region of 20 - 30mTorr for carrying out

etching processing. That is, a plurality of small diameter pumps having small exhaust rate are

advantageous in that they can cause a larger flow amount of gas at a low pressure region for

carrying out normal semiconductor processing than a single large diameter pump having a high

exhaust rate.

10      (Embodiment 46)

        Fig. 90 - Fig. 92 are plan views showing examples of the plasma device of the present

invention used as cluster tools for carrying out continuous processing by conveying between

vacuums.

        Fig. 90 is a case where rectangular process chambers and a rectangular wafer conveyance

15      chamber are joined together. Reference numeral 9001 is a wafer take in chamber, reference

numeral 9002 is a wafer take out chamber, reference numeral 9003 is a process chamber 1,

reference numeral 9004 is a process chamber 2, reference numeral 9005 is a wafer conveyance

chamber, and reference numeral 9006 is a gate valve. The process chambers 1 and 2 are any of

the chambers disclosed in Fig. 44, or Fig. 48 - Fig. 54. For example, process chamber 1 is an

20      etching chamber and process chamber 2 is a resist ashing chamber. One or a plurality of wafer

conveyance ports are provided inside the wafer conveyance chamber 9005, and wafer delivery is

carried out for the process chamber and the wafer take in/take out chambers.

        In the example of Fig. 90, miniature process chambers are efficiently arranged, and the

area that the cluster tool occupies in the clean room is extremely small. It is possible to make the

25      footprint of a cluster tool for a wafer having a diameter of 300mm even smaller than the smallest

footprint of a cluster tool for a wafer of 300mm in the related art. With the structure of ~~fig. 90~~

Fig. 90, the footprint of a cluster tool for a 300mm diameter wafer is $3.64mm^2$, which is about 0.9

times the footprint of the smallest cluster tool for a 200mm diameter wafer in the related art. The

number of chambers connected to the conveyance chamber is not limited to six.